Final Report (1 July 05)

Risk Assessment of Fuel Management Practices on Hillslope Erosion Processes (Phase I) 98-1-4-12

Project Location: Moscow, ID; Boise, ID; Riverside, CA

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Duration: 3 years (continued under Risk Assessment of Fuel Management Practices on Hillslope Erosion Processes Phase II, 01-3-02-08). This report covers accomplishments made during Phase I, which ended September 30, 2001. Phase II will end on September 30, 2005 and will be reported separately.

Executive Summary

After wildfires, the use of rapid response field protocols allowed measurements of postfire soil infiltration, soil erodibility, and hillslope erosion rates, while long-term measurements provided data on postfire rehabilitation treatment effectiveness and general recovery rates. These data were used to expand and validate the current suite of web-based erosion prediction tools, and to develop a conceptually different erosion risk management tool, ERMiT.

ERMiT's probabilistic analysis not only accounts for the variability in climate, soil properties, and spatial burn severity at the hillslope scale, but also provides the probabilistic output needed for postfire risk analysis. The custom interface is designed for use by hydrologists and soil scientists and is available to the public, along with our other erosion prediction tools, on the Internet.

In years 1999, 2000, and 2001, numerous technology transfer opportunities were used to deliver the basic findings from this research and to introduce the new ERMiT model design. Presentations were given at workshops and conferences and to postfire rehabilitation teams. Peer-reviewed journal articles and conference proceedings were instrumental in disseminating the science findings.

Introduction

Since variability is a dominant characteristic of both weather and postfire soil physical properties, it is an inherent to erosion processes as well. The research and modeling efforts funded by Joint Fire Science Program were designed to evaluate and incorporate this variability into a probabilistic erosion model. In many forest conditions, and some rangeland conditions, erosion may be minimal under normal, vegetated conditions. However, when the site is disturbed by fire, logging, grazing, or other management activities, erosion rates can increase dramatically. Natural resource managers and postfire rehabilitation teams need access to tools that can reliably predict the increased soil erosion following wildfires as well as the potential erosion mitigation from specific treatments to apply cost/benefit analyses in decision-making processes.

Phase I—Goal and Objectives

We proposed to address the shortfall in our knowledge and ability to predict both the consequence of wildfires and prescribed fires, and the effectiveness of various erosion mitigation practices on sediment production for rangelands, chaparral, and forests.

The goal of this study was to carry out field research and develop a tool to assist resource managers in evaluating risks of fuel management practices on hillslope erosion processes.

The specific objectives were:

1. To determine the spatial and temporal variability in infiltration and erosion parameters needed to predict overland flow and soil detachment after wildfire.

2. To quantify effectiveness of erosion mitigation practices in reducing sediment production for specified design storms following wildfires.

3. To determine hillslope characteristics that govern dry ravel processes in order to develop a risk model.

4. To adapt existing technology and incorporate new information into an integrated management tool for predicting erosion risk from fire and fuel management practices.

5. To evaluate measured erosion rates and estimates of sediment production after wildfires at the upland watershed/catchment scale.

Accomplishments

Given that the largest post-disturbance erosion rates occur when high intensity rainfall occurs on steep hillslopes during the first year after severe wildfires, obtaining the needed data required that field sites be selected and equipment installed immediately after fire suppression. To accomplish this task, we developed a rapid response protocol that included advanced purchase and preparation of all equipment and tools, fire safety training for all field crews, and direct communication with the Fire Incident Command and the BAER team leader. In addition, these sites needed to be maintained for multiple years, which required the cooperation of the land managers and installation of remote monitoring equipment.

Field research work was initiated in 1998, immediately after the North 25 Fire. The rapid response protocol was used on other fires in each successive year of the project. Efforts were made to take advantage of the research potential within each site with a variety of study plans being implemented. Many sites have remained operational beyond Phase I of this project. The data collected have provided the needed parameters for erosion modeling (including soil infiltration, erosion, and recovery rates), evaluation of various erosion mitigation strategies, and validation of erosion model predictions.

Objective 1—Infiltration and erosion variation

Our infiltration and rill/interrill erodibility studies were completed in the field, rather than in a lab, to maintain the natural variability that occurs. Using rainfall simulator equipment owned by Soil and Water Engineering Unit and the Agricultural Research Service in Boise, field measurements were made immediately after the fire was controlled and repeated the following two years to measure the recovery rate over the first three postfire years. Experiments were done in forest and range lands to obtain measurements for high and low severity burn conditions, natural unburned areas, and on skid trails.

Infiltration and Erodibility Studies—Field Research Locations:

- North 25 Fire, Wenatchee National Forest, Washington
- Denio Fire, Winnemucca District, BLM, Nevada
- Valley Complex, Bitterroot National Forest, Montana

Findings:

- Concentrated flow, or rill, erosion causes downcutting and produces about 10 times as much erosion as raindrop impact/overland flow erosion.
- In rangelands, fire-induced water repellent soil conditions occur under the shrubs but not in the areas between shrubs. Infiltration is reduced 30 percent the first year, 15 percent

the second year, and 0 to 5 percent the third year.
- Some volcanic ash-caped soils are naturally water repellent and the fires cause only a slight increase in repellency.

Publications: # 6, 9, 10, 12

Objective 2—Mitigation

Millions of dollars are spent annually on erosion mitigation measures after wildfires and the effectiveness of these measures have had a range of evaluations. To quantify the effectiveness of some postfire mitigation practices, large-scale rainfall simulations and natural rainfall on hillslope plots and small-paired watersheds were used.

In 2000, a major fire year, an extensive research effort was launched on areas burned by the Valley Complex fires in the Bitterroot National Forest, Montana. First, a large-scale rainfall plus rill simulation experiment was used to compare three hillslope erosion barriers—contour-felled logs, straw wattles, hand-dug contour trenches—to one another as well as untreated control plots. Immediately after the rainfall and concentrated flow simulation experiment, a silt fence monitoring system was installed to continue to compare these treatments under natural rainfall for three years. During the natural rainfall experiment water and sediment were observed going around the end of the logs or wattles before the sediment storage was fully used. These observations motivated some re-engineering and it was found that by adding earthen berms and turning the ends of straw wattles upslope the storage capacity was increased by 10 to 16 percent and the sediment-laden runoff tended to pool behind the barrier as intended. [Note: This information was immediately disseminated to the Burn Area Emergency Response BAER teams on-site during the rehabilitation efforts. The information was immediately implemented.]

Postfire Hillslope Treatment Studies—Field Research Locations:
- Seeding and fertilizer, North 25 Fire, Wenatchee National Forest, Washington
- Erosion barriers (contour-felled log, straw wattle, hand-dug contour trench), Valley Complex fires, Bitterroot National Forest, Montana.
- Contour-felled log, Mixing Fire, San Bernardino National Forest, California

Findings:
- Seeding and fertilizer treatments, when used separately or in combination, did not reduced erosion as compared to the control. Hillslope erosion rates decreased by an order of magnitude with year after the fire.
- Contour-felled log erosion barriers are less effective at reducing erosion from short duration, high intensity rain events than from low intensity, longer duration events. Most runoff and sediment would go around the end the logs. End berms increase the sediment storage capacity of the erosion barrier.

Publications: # 1, 3, 5, 12

Objective 3--Dry Ravel

Dry ravel occurs when gravity, in combination with a ‘trigger event’ (disturbance), overcome the frictional resistance between soil particles on a marginally-stable hillslope causing the particles to roll downslope forming sediment deposits. In the arid and semiarid Southwest, dry ravel is a common form of hillslope erosion following wildfire. Sediment from dry ravel is deposited in upland channels, providing a ready source of material for subsequent fluvial transport and/or debris flows. Previous work had quantified dry ravel on steep lands in southern California for unburned, prescribed fire, and wildfire conditions. However, the hillslope characteristics that govern dry ravel were poorly understood. Knowledge of these controlling factors was determined in a laboratory experiment at the Riverside Fire Science Laboratory. Results from this experiment were used to define the physical processes necessary for modeling this hillslope erosion process.

Findings:

- Coarse soils produced more dry ravel than fine soils.
- Slope angles greater than 30 degrees are prone to dry ravel.
- Vegetation (stem) density had no effect on reducing dry ravel, except for a small portion of ravel material stored behind the vegetation stem.

Publications: # 13

Objective 4—Erosion Risk Management Tool (ERMiT)

A conceptual model for Erosion Risk Management Tool (ERMiT) was developed, using the Water Erosion Prediction Project (WEPP) model as the driver, to prediction erosion from postfire environments. ERMiT was a departure from traditional modeling approaches, which generally provide an ‘average erosion value’ for a given set of conditions. Because erosion after wildfires is not ‘an average’ but rather an anomaly, a probabilistic approach was developed that accounted for the variability in climate patterns, soil properties and burn severity that were observed. The output was to be specifically tailored to allow BAER teams and fuel and land managers to evaluate the relative risks for postfire erosion in range, chaparral, and forest lands. Results from the other Phase I project objectives provide the information used populate ERMiT’s database, develop or modify conceptual models of the processes being modeled, and to provide validation data for the model predictions. The model was reviewed by field personnel during 2001 development, and suggestions for desired outputs have been incorporated.

Findings:

- A conceptual model was developed to incorporate variability in weather conditions, burn severity and soil properties for postfire erosion prediction.
- Input file structures were developed that will allow modeling forest, range, and chaparral

areas.

Publications: # 4, 8, 9

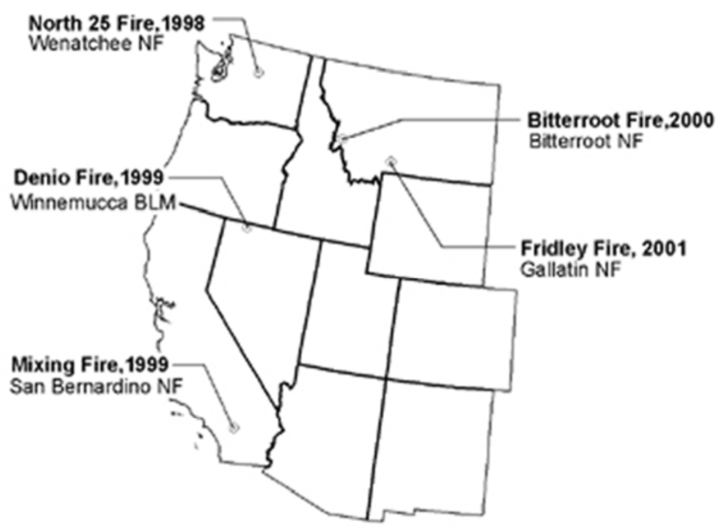
Objective 5—Post-wildfire Hillslope Runoff and Erosion

Past erosion research has focused on timber harvest operations and prescribed burn areas and have been (and continue to be) used to validate erosion predictions for these conditions. However, post-wildfire erosion research data from various habitats, such as forest, rangeland, and chaparral, were needed to verify estimates derived from existing and future erosion prediction models. To obtain these data, a rapid response protocol proved to be essential. Paired catchments and hillslope plots were installed to measure postfire runoff and erosion and, in some cases, to measure treatment effectiveness. These sites were/are monitored continuously for approximately five years.

Runoff and/or Sediment Measurement Study Sites—Field Research Locations:

Single Catchment
- Denio Fire, Winnemucca District, BLM, Nevada

Paired Catchments
- Contour Felled Logs, North 25 Mile Fire, Wenatchee National Forest
- Contour Felled Logs, Mixing Fire, San Bernardino National Forest, California
- Contour Felled Logs, Valley Complex, Bitterroot National Forest, Montana
- Contour Felled Logs, Fridley Fire, Gallatin National Forest, Montana



Hillslope Plots
- Denio Fire, Winnemucca District, BLM, Nevada
- North 25 Mile Fire, Wenatchee National Forest
- Mixing Fire, San Bernardino National Forest, California
- Valley Complex, Bitterroot National Forest, Montana

Findings:
- Short-duration high-intensity rainfall events are the driving factor in determining erosion

rates.

- An additional 10 to 15 percent of hillslope area is disturbed by the installation of contour felled logs.
- Erosion rates generally recover by an order of magnitude each successive year after a wildfire.

Publications: # 2, 3, 5, 6, 12, 14

Deliverables

As part of the continuing technology transfer of the WEPP-based erosion prediction technology, results obtained from this project were incorporated into the suite of erosion prediction models disseminated via the Internet (http://forest.moscowfsl.wsu.edu/fswepp) and in training workshops.

Numerous presentation have been made to hydrologists, soil scientists, fuel planners, BAER team leaders, engineers, ecologists from every federal land management agency, numerous state agencies, and private consults and land managers. Many informal discussions—on the phone, in emails, at BAER trainings and meetings, over the hood of the truck near a research site—have been instrumental in dissemination of new research findings. The specialist who needs this information does not want to wait for the formal research paper to be published, they want to know how best to predict erosion or what treatment will work best immediately.

Appendix I is the table of proposed deliverables from this Phase I project proposal. Nearly all of the objectives were met or exceeded except for #4. Although the concept of the ERMiT model was fully developed in Phase I, the coding of the interface was not completed until Phase II.

Presentations

1. Robichaud, P.R. Fire and erosion: what happens after the smoke clears . . . The Geological Society of America Annual Meeting, Denver, CO. October 1999.

2. Pierson, F.B. Hydrologic impacts of fire on the Boise Front. Seventh Biennial Watershed Management Conference. Joint Fires Science conference and workshop, Boise, ID. June 1999.

3. Robichaud, P.R., Beyers, J., Neary, D. Fire and Erosion: Effectiveness of postfire rehabilitation treatments. U.S. Geological Survey Second Wildland Fire Science Workshop. Los Alamos, NM. October 2000.

4. Pierson F.B., K.E. Spaeth, and D.H. Carlson. Fire effects on sediment and runoff in steep rangeland watersheds. 7th Federal Interagency Sedimentation Conference. US Subcommittee on Sedimentation. Washington DC. Feburary 2001

5. Robichaud, P.R. Effects of burn severity on erosion and watersheds. Fire Manager's Workshop, University of Idaho. Moscow, ID. March 2001.

6. Robichaud, P.R. Fire and erosion: What happens when the smokes clears. National Burned Area Emergency Rehabilitation Team Leader Training, Reno, NV. March 2001.

7. Robichaud, P.R. Erosion risk after wildfire. Region 4 Soils Workshop, Ogden, UT. April 2001.

8. Robichaud, P.R. Monitoring soil erosion using silt fences. Region 4 Soils Workshop, Ogden, UT. April 2001.

9. Robichaud, P.R. The hydrology of burnt forest soils. Idaho Water Resources Seminar, Video Interactive Moscow, Boise, Post Falls, and Twin Falls, ID. November 2001.

10. Elliot, W.J. Comparing erosion risks from forest operations to wildfires. 2001-A Forest Engineering Odyssey, The International Mountain Logging and 11th Pacific Northwest Skyline Symposium, Seattle, WA. December, 2001.

11. Robichaud, P.R. Fire and erosion: what happens after the smoke is gone? 12th Annual Nonpoint Source Water Quality Monitoring Workshop, Boise, ID. January 2002. Abstract provided.

12. Robichaud, P.R. Dirty work on the Bitterroot: first year erosion results. Bitterroot Restoration Team, Bitterroot National Forest Leadership Team, Hamilton, MT. May 2002.

Publications from Phase I

1999

1. Fend. J.F., J. Thornton, D. Rittenhouse, F.B. Pierson, C.R. Micklelson and C.W. Slaughter. 1999. The science and politics of the 1996 Boise Front Fire – what we learned from the 8th Street rehabilitation effort. In: C.W. Slaughter (ed.), *Western Watersheds: Science, Sense and Strategies.* Proceedings of the Seventh Biennial Watershed Management Conference. Water Resources Center Report NO. 98. University of California, Davis. CA.

2. Pierson, F.B. Hydrologic impacts of fire on the Boise Front. 1999. In: C.W. Slaughter (ed.), *Western Watersheds: Science, Sense and Strategies.* Proceedings of the Seventh Biennial Watershed Management Conference. Water Resources Center Report No. 98. University of California, Davis. CA. 10 p.

2000

3. Robichaud, P.R. 2000. Fire and erosion: evaluating the effectiveness of a post-fire rehabilitation treatment, contour-felled logs. *Proceeding, Watershed Management 2000, American Society of Civil Engineers, Ft. Collins. June 20-24, 2000. 11 p.*

4. Robichaud, P. R., W. J. Elliot, F. B. Pierson, and P. M. Wohlgemuth. 2000. Risk assessment of fuel management practices on hillslope erosion processes. In: Neuenschwander, L.F. and K.C. Ryan (eds.) *Crossing the Millennium: Integrating Spatial Technologies and Ecological Principles for a New Age in Fire Management*. Proceedings of Joint Fire Science Conference and Workshop, Reno, NV p. 58-65.

5. Wessman, L., L. Juarros and F.B. Pierson. 2000. Eighth Street Fire monitoring efforts in the Boise foothills. Technical Report. In: *Watershed Management Council Networker*. Watershed Management Council, Davis, CA. Winter Edition.

6. Robichaud, P.R. 2000. Forest fire effects on hillsope erosion; what we know. . In: *Watershed Management Council Networker*. Watershed Management Council, Davis, CA. Winter Edition.

2001

7. Brady, J.A., P.R. Robichaud, F.B. Pierson. 2001. Infiltration rates after wildfire in the Bitterroot Valley. *American Society of Agricultural Engineers Annual Meeting*, Sacramento, CA. July 2001. Paper No. 01-8003. 11 p.

8. Elliot, W.J, P.R. Robichaud, D.E. Hall, C.O. Cuhaciyan, F.B. Pierson, P.M. Wohlgemuth. 2001. A probabilistic approach to modeling erosion for spatially-varied conditions. *American Society of Agricultural Engineers Annual Meeting*, Sacramento, CA. July 2001. Paper No. 01-8006. 16 p.

9. Elliot, W.J. P.R. Robichaud, C.D. Pannkuk. 2001. A probabilistic approach to modeling erosion for spatially-varied conditions. *Proceedings of the seventh Federal Interagency Sedimentation Conference*, March 2001, Reno, NV. Volume 2 (VI):33-40.

10. Pierson, F.B., P.R. Robichaud, K.E. Spaeth. 2001. Spatial and temporal effects of wildfire on the hydrology of step rangeland watershed. *Hydrological Processes 15(15):2905-2916.*

11. Pierson F.B., K.E. Spaeth, and D.H. Carlson. 2001. Fire effects on sediment and runoff in steep rangeland watersheds. In: *Proceedings of the 7th Federal Interagency Sedimentation Conference*. pp. X33-X40. US Subcommittee on Sedimentation. Washington DC, USA.

12. Wohlegemuth, P.M., K.R. Hubbert, P.R. Robichaud. 2001. The effects of log erosion barriers on post-fire hydrological response and sediment yield in small forested watersheds, Southern California. *Hydrological Processes 15(15): 3053-306.*

13. Wohlegemuth, P.M. 2001. Dry ravel experiment. Report on file at USDA Forest Service, Pacific Southwest Research Station, Riverside Fire Laboratory, Riverside, CA.

14. Elliot, W.J., P.R. Robichaud. 2001. Comparing erosion risks from forest operations to wildfires. In: Schiess, P. and F Krogstad (eds.) Proceedings, 2001-A Forest Engineering Odyssey, The International Mountain Logging and 11th Pacific Northwest Skyline Symposium, Seattle, WA. December 10-12, 2001.pp. 78-89

Appendix 1. Proposed deliverables.

Objective	Deliverable	Date
1. Infiltration and Erosion Verification	• At least two technical papers on spatial and temporal variation of conductivity following a severe fire, one applicable to forests and one to rangelands	3 years after severe fire
	• Two research papers for Tech Transfer	4 years after fire
2. Mitigation	• Technical paper on results of study	Year 3
	• General Technical Report with management recommendations	Year 4
3. Dry Ravel	• Technical paper on research findings	Year 3
	• Dry ravel conceptual model and paper	Year 4
4. Erosion Risk Management Tool	• Computer interface with database	Initial release year 3
	• Presentation of technology at workshops	From year 2
	• Technical paper on technology	Year 4
5. Post-wildfire Runoff and Erosion	• At least two technical papers on field observations	3 years after severe fire